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BULLETIN 252 DECEMBER, 1923

IMP. BUR.
26 MAR. 1924

Connecticut Agricultural Experiment Station

NEW HAVEN, CONN.

The European Red Mite

PHILIP GARMAN

Figure 1. European Red Mite, greatly enlarged.

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December, 1923.

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The European Red Mite in Connecticut Apple Orchards.

Paratetranychus pilosus Can. & Fanz.

By Philip Garman, Ph.D.

Brown foliage, a result of the feeding of the European red mite, was first noticed on apples in Connecticut in 1920, when a block of Baldwins in a large commercial orchard near Branford became discolored. Since that time the trouble has increased rather than decreased in the State, and the mite now seems to be well established, threatening serious damage in some sections every year. What can be done to hold it in check has been asked from time to time, and we are now able to offer what seems to be a practical remedy, together with facts about habits and life history of the mite which should enable the orchardist to gain control.

History.

The European red mite was described in 1876 from Italy: it has been noticed in several countries of Europe having been given considerable attention as a pest in Sweden. In America it has been present for many years, but has been confused with other species, notably, the clover mite (*Bryobia pretiosa* Koch) and the common red spider (*Tetranychus bimaculatus* Harvey) from both of which it is distinct. On the Pacific coast it has passed under the name of citrus mite and apparently others, and has done serious damage in that locality. It was noted in Canada in 1915,[1] by Frost in Pennsylvania[9] in 1919, was found in Connecticut in 1920,[10] and since then has been reported from Maryland, New York and Ohio. The mite was recognized as present in California by Essig[4] in 1922, though it has probably been there much longer.

Nature of the Injury.

A heavy infestation of red mites turns leaves of apple trees brown early in June, and if continued gives them a dead appearance in July. This results in undersized and poorly colored fruit and affects the vitality and set of fruit for the following season. On plums and apples, a little later, there is considerable defoliation. A moderate infestation leaves the trees with sickly foliage and prevents growth of fruit the latter part of the summer, a condition

often unnoticed by the orchardist, but very conspicuous as compared with trees free of mites.

Distribution.

The red mite is present in Connecticut, Massachusetts, New Jersey, New York, Maryland,[12] Pennsylvania, West Virginia and Ohio. It has also been reported from Canada. In the west, Oregon and California consider it worthy of attention and it will probably be found in many other localities where perhaps it is not numerous enough at present to invite attention.

In Connecticut it is well distributed, having been seen in, or received from, Fairfield, Hartford, Middlesex, New Haven and New London Counties. The most serious damage seems to have been done in the southern part of the State and little complaint has been heard from the more northern counties.

Host Plants.

The species has been found by the author on rose, pear, peach, plum, cherry, apple and elm. It is reported to infest prune trees in Pennsylvania,[2] and is known to infest almond, prune and citrus fruits in California.[3] Most damage is done to apples and plums in Connecticut, though occasionally peach trees in the vicinity of infested apples have been injured.

Habits and Life History.

Examine an infested tree in winter after the leaves have fallen and you will note on branches the size of a lead pencil (sometimes on those as much as two inches in diameter) a coating of small red eggs, which if numerous enough will not require magnification to see them. They are dark red in color and are most abundant around bud scars and in crevices—resembling a coating of red brick dust. Wise orchardists know the signs and know that trouble may be in store—and act accordingly. These are the winter eggs, which carry the pest over from season to season. Watch carefully and you will find them hatching about the middle of April or first of May; or, in terms of the development of the apple tree, at the time when the blossom buds of most varieties begin to show pink; better still when the leaves are about an inch long. From the twigs the young mites make their way to the leaves and begin to feed, completing their development in two weeks, but sometimes requiring longer if a cold spring is at hand. By the first of June, conditions being favorable, they begin to multiply rapidly, passing the entire cycle in three weeks or shorter if the weather is warm. The life period is such that an overlapping of broods now begins for the following reasons. The egg develops in 6–13 days or an average of nine days, and the mites require

about as long to complete their development, or long enough to begin laying eggs (nine days more). If we now allow 15 days as the average life of the adult during which time the eggs are laid, not all at one time but a few each day, then at the end of 15 days under favorable conditions the first eggs of the particular female will have hatched and will be well along to maturity, giving two different generations on the leaf at one time. This apparently takes place shortly after the first of June in Connecticut, making it impossible to apply separate sprays for different broods during the summer. In all, considering the length of the cycle, some six generations might easily occur in a single summer, but it is not always safe to figure natural laws or processes by such simple mathematics. The number of generations in this case is of minor importance, but our experience indicates that most damage is done in June and early July when multiplication is most rapid, and before enemies become numerous.

The female is not a great egg layer, but is capable of laying as many as 34 eggs, at the rate of one or two per day. By the middle of August, many eggs are laid on the twigs and in the calyx and stem cavities of the fruit, and by September 15 the winter eggs are being laid rapidly. The adults die shortly after and show no tendency to hibernate in this climate.

The time required for development in each stage is shown in the following tables:

TABLE 1—LENGTH OF INCUBATION PERIOD.

Eggs Laid	Eggs Hatched	Period, Days	Mean Temp., F.
May 16	May 29	13	63.2
May 18	May 29	11	64.2
May 21	May 29	8	....
May 21	June 1	10	67.2
June 24	June 30	6	....
June 24	June 30	6	....
July 11	July 17	6	73.1
Aug. 6	Aug. 14	8	....
Aug. 8	Aug. 16	8	....
Aug. 8	Aug. 17	9	....
Aug. 29	Sept. 6	8	....
Aug. 16	Aug. 30	14	65.5
Aug. 17	Aug. 30	13	66.4
Sept. 3	Sept. 9	6	72.0

TABLE 2—PERIOD FROM EGG TO ADULT.

Egg Hatched	Adult Obtained	Period, Days	Mean Temp., F.
May 29	June 5	7	66.6
June 1	June 8	7	....
June 9	June 19	10	65.1
June 10	June 17	7	....
July 11	July 16	5	77.1
July 25	Aug. 1	7	72.9
July 25	Aug. 3	9	....
Aug. 30	Sept. 9	10	....
Aug. 14	Aug. 23	9	65.4

TABLE 3—PREOVIPOSITION PERIOD OF ADULT FEMALE.

Female Emerged	First Egg Laid	Period, Days	Mean Temp., F.
June 7	June 10	3	61.0
July 8	July 9	1	71.3
July 16	July 19	3	79.2
July 16	July 19	3	79.2
Aug. 6	Aug. 8	2	....
Aug. 10	Aug. 17	7	71.8
Sept. 9	Sept. 11	2	....

TABLE 4—LENGTH OF LIFE OF ADULTS.

Adult Emerged	Adult Died	Period, Days	Mean Temp., F.
June 7	June 21	14 (female)	....
June 9	June 30	21	....
July 8	July 22	14 (female)	79.0
July 16	July 22	6 (female)	82.2
Aug. 10	Aug. 29	19 (female)	68.1
Aug. 3	Aug. 17	14 (male)	74.8
Aug. 6	Aug. 19	13 (female)	....

TABLE 5—EGGS LAID BY ADULT FEMALES.

First Egg	Adult Died	Total Number
June 10	June 21	18
July 9	July 22	22
June 10	June 21	16
June 9	June 30	34

TABLE 5a—LIFE HISTORY OF EUROPEAN RED MITE.†

Eggs Laid	Eggs Hatched	Adult Obtained	Eggs from Adult	Total Period, Days
May 21	May 29	June 5 (male)	.....	15
May 21	.....	June 7	June 10	20
July 5	.....	July 16 (male)	.....	11
July 7	.....	July 16	July 19	12
July 21	.....	Aug. 3 (male)	.....	13
July 19	July 25	Aug. 1 (male)	.....	13
Aug. 6	Aug. 14	Aug. 23	.....	17

Early stages feed mostly on the underside of the leaf, but as the leaf becomes crowded, many adults move to the upper surface and feed there. Very little web is spun at any stage, the larvae and nymphs spinning more than the adults.

METHODS OF SPREAD.

Wind is the most important agent in local distribution of the red mite. Many spin down from the leaves on short threads and if a strong wind is blowing, are probably carried for a considerable distance. Distribution of infested nursery stock is probably responsible for spread of the mite since the eggs are small and easily overlooked. Probably many are carried on the fruit, especially winter apples, which sometimes contain eggs in calyx and stem cavities.

† Continuous records of single individuals.

The Different Stages.

The European red mite passes through the following stages:—egg: active larva—quiescent larva: active first nymph—quiescent first nymph: active second nymph—quiescent second nymph: adult male or female. During quiescent periods the mites are inactive and no food is taken. The male usually emerges shortly before the female and awaits the emergence of the latter. Eggs are laid within a few days after emergence of the adult female. There is no difference in the number of immature stages of male and female.

Description.

Adult females are dark velvety red in color, the nymphal stages and the male dark brown or green. Winter eggs are dull red, summer eggs usually brown.

Egg—Slightly flattened above, radially grooved and with a short stalk arising from the center, the stalk being longer than the vertical diameter of the egg. Transverse diameter of egg .15 mm.

Larva—Nearly orange in color when recently hatched, later turning dark green or brown; mite with three pairs of legs; length .16–.18 mm.

Protonymph—Very dark green or brown in color; with four pairs of legs, the latter quite pale; length .19–.25 mm.

Deutonymph—Very dark green or brown; legs paler; length .25–.30 mm.

Adult, female—Color dark velvety red or brown with conspicuous white dots on dorsum at base of setae; 26 setose dorsal bristles in all; tarsi provided with a single claw widest at the mid point and with apparently five (there are probably six) appendiculate spurs projecting at right angles (Fig. 2, 4); four tenent hairs with hooked tips arise from the base of the claw and exceed it considerably in length; collar tracheae consisting of a single tube (Fig. 2, 3) dilated at tip to form a spherical chamber; maxillae consisting of four segments, the last tipped with a short spatulate body, probably representing an additional segment; next to the last segment with a strong hook, and the last with five setae (two apical, two basal on the dorsum, and one lateral) and a clavate hair between the two dorsal pairs; length of adult, .28-.31 mm.

Male—Much smaller than the female, the tip of the abdomen being much more pointed and the color usually brown, never red; genitalia as in Fig. 2, 5; length .26–.28 mm.

Difference from Other Economic Species.

There are abundant differences between the European red mite and the common red spider, *Tetranychus bimaculatus* Harvey. The dorsal setae are smaller in the latter species and the collar tracheae are much different, being hooked and segmented (see Fig.

2, 8). The eggs are spherical, usually pale, and without grooves or stalk.

Bryobia pretiosa Koch,† the clover mite, is distinguishable at sight, being considerably flatter and wrinkled above and with a number of flat scalloped plates around the margin of the body of the adult. There are two claws on each tarsus instead of one and the front pair of legs is much longer than any of the others. The eggs are red but are larger, usually measuring .19–.20 mm. in diameter, and lack the radial grooves and the dorsal stalk present in *P. pilosus*.

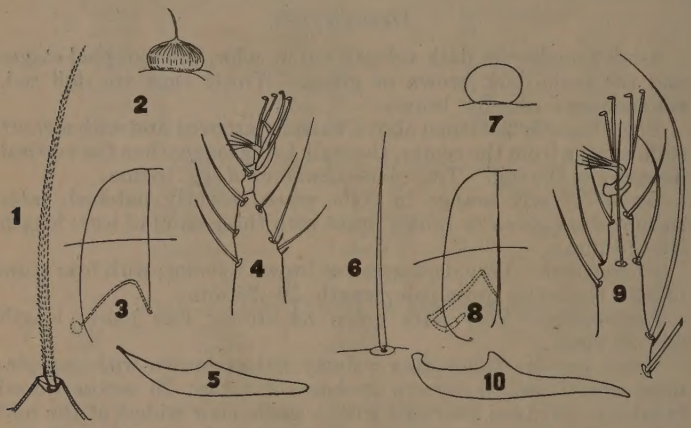


Figure 2. Structures of European red mite, *Paratetranychus pilosus* Can. and Fanz. and common red spider, *Tetranychus bimaculatus* Harvey.

1, *Paratetranychus pilosus*, seta of dorsum 846 times enlarged; 2, egg, 14 times enlarged; 3, collar tracheae and mandibular plate, 714 times enlarged; 4, tarsus of first pair of legs of female, 921 times enlarged; 5, penis, 1400 times enlarged.

6, *Tetranychus bimaculatus*, seta of dorsum, 846 times enlarged; 7, egg, 14 times enlarged; 8, collar tracheae and mandibular plate, 714 times enlarged; 9, tarsus of first pair of legs of female, 921 times enlarged; 10, penis, 1400 times enlarged.

Number of Mites Necessary to Produce Browning.

Some varieties of apples withstand much more of an infestation without showing the effects than others. Spy and Wealthy trees were browned in 1923 by 12 to 33 mites per leaf, estimated from the number of cast skins found after browning was noticed. Hurlbut trees with 55 to 133 per leaf suffered severe browning.

† *Bryobia pratensis* Garman.

Varietal Preferences.

Greening trees rarely have as many mites per leaf as other varieties, and no instances have been observed in Connecticut where severe injury has been done to this variety. Baldwin is perhaps the most commonly injured, but Hurlbut, York Imperial, McIntosh, Wealthy, Northern Spy and Fall Pippin have been injured, in some cases severely. Thin leaved varieties are most susceptible.

Natural Enemies.

Some of the most puzzling features of the appearance and disappearance of the red mite are connected with the occurrence of predaceous enemies. An orchard may, for instance, be heavily infested one season and show almost no mites the following year, although no spraying has been done in the meantime. This is often, though not always explained by the presence of enemies which in Connecticut seem able to conquer and almost eradicate the mite once every two or three years. Thus in 1922, a heavy infestation at North Branford was reduced almost to the zero point and no outbreak occurred the following year. In 1923, thrips, coccinellids, and small Hemiptera such as *Triphleps insidiosa* were numerous in orchards, and greatly checked the mite in several places.

Three species of thrips† were found, a small bug‡, a lady beetle§, a predaceous mite‖, and a small undetermined Neuropteron. All of these destroyed eggs of the red mite with relish, one thrips being observed to eat 19 eggs in twenty-four hours, while an adult *Stethorus* on being observed took six eggs and three mites within five minutes.

Enemies of the red mite are most numerous in July and August and when numerous enough keep the pest in check in spite of its rapid multiplication at this time of year. One or two thrips per leaf are apparently enough to keep in advance of an infestation because of their enormous appetite for mite eggs, and their habit of attacking mites themselves when eggs are scarce. They often leave the foliage and twigs with empty transparent egg shells, having sucked out their contents and departed.

Weather Conditions Affecting Abundance.

Adverse weather conditions are responsible for subsidence of outbreaks in some cases, but it is sometimes difficult to say whether this or the abundance of enemies is the cause. Conditions favorable to the mite may be favorable to development of the enemies or vice-versa. It has been reported that bad outbreaks have followed a very severe winter and the great numbers of mites in 1920 and

† *Leptothrips mali* Fitch, *Scolothrips 6-maculatus* Pergande and *Haplothrips* sp.; determined by Dr. A. C. Morgan.
‡ *Triphleps insidiosa* Say.
§ *Stethorus punctum* Leconte.
‖ *Seius pomi* Parrott.

1923 certainly followed abundant snows and cold weather. However, a serious outbreak occurred in 1922 after a rather mild winter, and the infestations in 1923 did not become serious until midsummer, whereas if cold weather had much effect this should have begun more promptly. Heavy rainfall or better a series of showers at frequent intervals in summer is successful in keeping an infestation from gaining headway, as witnessed in this State in 1922. This is due to the fact that many mites are washed from the leaves and are unable to regain the tree. It is quite possible that a rainy period in September would decidedly affect the abundance of the mite the following season, though no cases of this sort have been observed. In 1923, the prolonged dry period from the middle of June to September favored development and several orchards were damaged severely.

Control Measures.

Owing to the uncertainty that weather and enemies will produce a balance in favor of the orchardist, treatments for control must be considered and a regular schedule adopted. There are periods when the mite is especially vulnerable and a thorough spray is of much value; and it is a good policy to learn to know the mite in its different stages so that damage may be anticipated and prevented. As with many insects the best time to concentrate efforts is in early spring and sprays at this time should go far towards a control for the entire season, especially in this climate. It is well, therefore, to keep a sharp lookout for winter eggs when the annual pruning is done and not to wait until the leaves turn brown before considering treatment.

Sprays for the Winter Eggs.

The first attack should be on the overwintering eggs which may be reached with sprays and largely destroyed. Laboratory tests were conducted in 1920-21 with a view to finding the most effective treatments for this purpose. Some of the tables are given below together with tests of several other compounds reaching us since these were made.

In the tables, the names of a number of proprietary compounds appear, and the following explanation in regard to their general composition and source is necessary. Such compounds as lime-sulphur, and Scalecide are too well known to need comment.

"*Jarvis Compound.*"— A miscible oil containing phenol; manufacturer J. T. Robertson; obtained from Apothecaries Hall Co., Waterbury, Conn.

"*Kero-spray.*"—A commercial kerosene emulsion; manufacturer, Kero-Spray Co., 198 9th St., Jersey City, N. J.

"*Keresol.*"—An oil spray containing 70 per cent. kerosene; obtained from Mr. A. A. Claasen, Mascher and Turner Streets, Philadelphia, Pa.; effect of spray on trees unknown.

"Sulco V. B."—A spray containing fish-oil and small per cent. phenol; manufactured by Cook & Swan Co., 148 Front St., New York; obtained from Apothecaries Hall Co., Waterbury; effect on apple trees unknown, probably safe.

"Wormol."—A miscible oil recommended for use against peach borers by the General Chemical Company; obtained from General Chemical Company, 25 Broad St., New York, N. Y.; effect upon apple trees unknown.

"B. T. S."—Barium tetrasulphide, a lime-sulphur substitute; a General Chemical Company product.

"Sunoco Spraying Oil".—A miscible mineral oil; apparently safe on apple trees; sold by Sun Oil Company, Philadelphia, Pa.

"Target Brand Scale Destroyer."—A miscible oil containing phenol; sample submitted by the Interstate Chemical Company, Jersey City, N. J.

TABLES SHOWING RESULTS OF TREATING EGGS OF EUROPEAN RED MITE WITH DIFFERENT INSECTICIDES.

TABLE 6.

Exp. No.	Treatment	Total Number of Eggs Used	Number Hatched	Per Cent. Hatched	Date Treated	Date Examined
1.	Kerosene emulsion (10 per cent. kerosene)	660	402	60.9	Mar. 16	Apr. 29
2.	Kero-spray 1 part-25 parts water	298	166	56.0	"	"
3.	Sulco V. B. 1 part-25 parts water	502	255	50.7	"	"
4.	Keresol 1 part-18 parts water	442	265	59.9	"	"
5.	Jarvis Compound 1 part-15 parts water	104	6	5.7	"	"
6.	Scalecide 1 part-15 parts water	237	22	9.2	"	"
7.	Lime-sulphur 1 part-9 parts water	652	253	38.8	"	"
8.	Dry lime-sulphur 12 lbs.-50 gals. water	418	125	29.9	"	"
9.	B. T. S. 12 lbs.-50 gals. water	349	162	46.4	"	"
10.	Scalecide 1 part-25 parts water	341	115	33.7	"	"
11.	Check no treatment	265	151	56.9	—	"
12.	Scalecide 1 part-15 parts water	150	8	5.3	April. 7	Apr. 29
13.	Scalecide 1 part-15 parts water	669	9	1.3	"	"
14.	Scalecide 1 part-35 parts water	838	53	6.3	"	"
15.	Scalecide 1 part-25 parts water	744	68	9.1	"	"
16.	Scalecide 1 part-50 parts water	462	47	10.1	"	"
17.	Check no treatment	253	164	65.0	—	"
18.	Check no treatment	100	45	45.0	—	"

TABLE 7.

Exp. No.	Treatment	Total Number of Eggs Used	Number Hatched	Per Cent. Hatched	Date Treated	Date Examined
	Lime-sulphur 1-9					
1.	Nic. Sulphate 1-500	649	189	29.1	Dec. 29	Feb. 23
2.	" " "	2,166	544	25.1	Feb. 8	Mar. 2
	Lime-sulphur					
3.	1 part-9 parts water	403	45	11.1	Apr. 5	Apr. 15
4.	" " "	378	18	4.7	Mar. 12	Mar. 28
5.	" " "	773	268	34.6	Dec. 29	Feb. 23
	Lime-sulphur 1-9					
6.	Nic. Sulphate 1-500	165	80	48.4	Apr. 13	Apr. 28
7.	" " "	221	54	24.4	Apr. 13	Apr. 29
	Lime-sulphur					
8.	1 part-9 parts water	526	351	66.7	Dec. 29	Apr. 28
9.	" " "	652	253	38.8	Mar. 16	Apr. 29
10.	" " "	449	132	29.4	Feb. 17	May 3
11.	" " "	299	83	27.7	Mar. 10	May 2

Notes.

Table 6. Eggs in tests 1-11 were taken from the same branch. Those in 12-18 were from another branch. All eggs dipped in the different solutions, not sprayed.

Table 7. Nos. 1-5 were kept indoors after treatment; 6-11 outdoors. Nos. 5 and 6 were sprayed, other dipped.

TABLE 8.

	Dry lime-sulphur					
1.	½ oz.-1 pint water	302	114	37.7	Apr. 5	Apr. 15
2.	" " "	274	6	2.1	Mar. 12	Mar. 28
3.	" " "	197	74	37.5	Mar. 4	Mar. 25
4.	" " "	418	125	29.9	Mar. 16	Apr. 29

TABLE 9.

	B. T. S.					
1.	½ oz.-1 pint water	1,047	368	35.2	Feb. 8	Mar. 2
2.	" " "	374	124	33.2	Apr. 5	Apr. 15
3.	" " "	438	35	7.9	Mar. 12	Mar. 28
4.	" " "	234	34	14.5	Mar. 4	Mar. 25
5.	½ oz.-1 pint water	349	162	46.4	Mar. 16	Apr. 29
	B. T. S. ½ oz.-1 pt. water					
6.	N.S. 1 part-500 part water	282	126	44.6	Apr. 5	Apr 29

TABLE 10.

1.	Scalecide 1-15†	773	27	3.5	Dec. 29	Feb. 23
2.	" 1-15	1,078	0	0.0	Feb. 8	Mar. 2
3.	" 1-15	412	0	0.0	Apr. 5	Apr. 15
4.	" 1-15	67	0	0.0	Mar. 12	Mar. 28
5.	" 1-25	173	0	0.0	Mar. 16	Apr. 4
6.	" 1-50	356	11	3.0	Mar. 16	Apr. 4
7.	" 1-15	119	0	0.0	Mar. 4	Mar. 25
8.	" 1-15	409	135	33.0	Dec. 29	Apr. 28
9.	" 1-15	104	6	5.7	Mar. 8	Apr. 29

† Proportions of Scalecide to water.

TABLE 10—*Continued.*

Exp. No.	Treatment	Total Number of Eggs Used	Number Hatched	Per Cent. Hatched	Date Treated	Date Examined
10.	Scalecide 1-25	341	115	33.7	Mar. 9	Apr. 29
11.	" 1-50	150	8	5.3	Apr. 7	Apr. 29
12.	" 1-15	669	9	1.3	Apr. 7	Apr. 29
13.	" 1-25	744	68	9.1	Apr. 7	Apr. 29
14.	" 1-35	838	53	6.3	Apr. 7	Apr. 29
15.	" 1-50	462	47	10.1	Apr. 7	Apr. 29
16.	" 1-15	326	55	16.8	Feb. 17	May 3

Notes.

Table 8. Nos. 1-3 kept indoors, 4 outdoors.

Table 9. Nos. 1-4 kept indoors, 5 and 6 outdoors.

Table 10. Tests 1-7 were kept indoors after treatment; 8-16 were kept outdoors. Numbers 10-15 were sprayed, others were dipped in spray solutions.

TABLE 11.

Exp. No.	Treatment	Total No. of Eggs Used	No. Hatched	Per Cent. Hatched	Date Treated	Date Examined
1.	Sunoco spraying oil 1-15	233	4	1.7	Feb. 1	Mar. 8
2.	Sunoco spraying oil 1-15	262	1	.4	Mar. 15	Apr. 15
3.	Sunoco spraying oil 1-25	180	6	3.3	Mar. 15	Apr. 15
4.	Sunoco spraying oil 1-50	325	56	14.1	Feb. 3	Mar. 8
5.	Lime-sulphur, 1-6.....	297	68	22.8	Feb. 3	Mar. 8
6.	Lime-sulphur, 1-9.....	224	77	29.4	Feb. 3	Mar. 8
7.	Target brand scale destroyer, 1-15.....	357	3	.8	Feb. 3	Mar. 8
8.	Target brand scale destroyer, 1-50.....	265	37	13.9	Feb. 3	Mar. 8
9.	Red engine oil 1% emulsion with fish oil soap..	299	0	.0	Mar. 15	Apr. 15
10.	Red engine oil 2% emulsion with fish oil soap..	322	2	.6	Mar. 15	Apr. 15
11.	Scalecide 1-15.....	252	4	1.5	Mar. 15	Apr. 15
12.	Check, no treatment....	200	143	71.5	———	Mar. 8
13.	Check, no treatment....	175	136	77.7	———	Apr. 15
14.	Lime-sulphur 1-8.....	666	148	22.2	Apr. 11	May 15
15.	Scalecide 1-15.....	644	2	.3	Apr. 11	May 15
16.	Sunoco spraying oil 1-15	573	2	.3	Apr. 11	May 15
17.	Red engine oil 2% emulsion with fish oil soap..	646	31	4.8	Apr. 11	May 15
18.	Check, no treatment....	361	127	35.1	———	May 15

TABLE 12 (CHECKS).

Exp. No.	Total Number of Eggs Used	Number Hatched	Per Cent. Hatched	Date Obtained	Date Examined
1.	1,956	345	17.6	Dec. 29	Feb. 23
2.	527	263	49.9	Feb. 9	Mar. 4
3.	60	45	75.0	Feb. 10	Mar. 4
4.	2,421	1,477	61.0	Feb. 8	Feb. 23
5.	334	326	97.6	Apr. 5	Apr. 15
6.	359	324	90.2	Apr. 8	Apr. 28
7.	208	185	88.9	Mar. 4	Mar. 25
8.	402	223	55.4	Mar. 10	Mar. 28
9.	403	333	82.6	Mar. 11	Mar. 28
10.	430	342	79.7	Mar. 12	Mar. 28
11.	255	209	81.9	———	Apr. 4

TABLE 12 (CHECKS)—*Continued.*

Exp. No.	Total Number of Eggs Used	Number Hatched	Per Cent. Hatched	Date Obtained	Date Examined
12.	421	181	42.9	Dec. 29	Apr. 28
13.	265	151	56.9	Mar. 16	Apr. 29
14.	253	164	64.8	Apr. 7	Apr. 29
15.	100	45	45.0	Apr. 7	Apr. 29
16.	162	109	67.3	Apr. 13	Apr. 28
17.	120	20	16.6	Apr. 4	Apr. 28
18.	155	85	54.8	Apr. 5	Apr. 29
19.	531	337	63.4	Feb. 17	May 3
20.	188	114	60.6	Mar. 10	May 2

COMPARATIVE MORTALITY OF TREATED EGGS OF EUROPEAN RED MITE, KEPT OUTDOORS AND INDOORS AFTER TREATMENT.

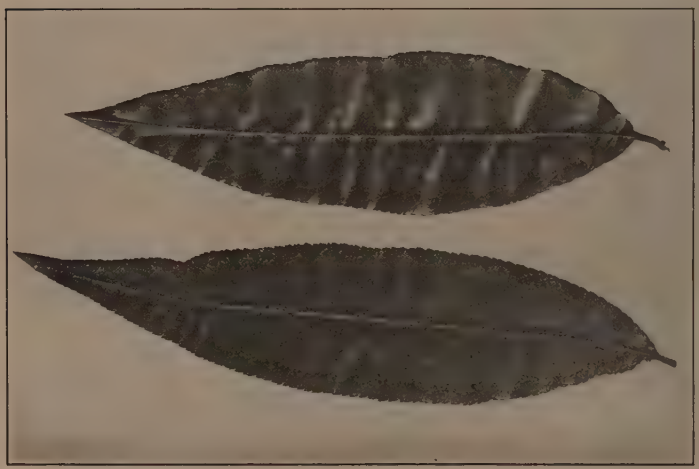
TABLE 13.

Treatment	Hatched Per Cent.	Possible Kill Per Cent.	Number of Eggs Used	
Check, no treatment	61.0	0	7,355	Indoors
	54.9	0	2,195	Outdoors
Kero-spray	86.5	0	445	Indoors
	55.7	0	298	Outdoors
Sulco V. B.	49.9	18.6	879	Indoors
	48.0	12.5	958	Outdoors
Keresol	34.2	44.0	385	Indoors
	59.9	0	442	Outdoors
Linseed oil emulsion	56.0	8.4	841	Indoors
	26.1	52.5	352	Outdoors
B. T. S.	26.7	56.3	2,093	Indoors
	45.6	16.8	631	Outdoors
Lime-sulphur; liquid 1-9	22.1	63.8	3,596	Indoors
	43.1	21.4	2,515	Outdoors
Lime-sulphur; dry	25.0	59.0	773	Indoors
	29.9	45.5	418	Outdoors
Kerosene emulsion	31.6	48.2	227	Indoors
	60.9	0	660	Outdoors
Wormol, 1 part in 15 parts water	5.4	91.1	419	Indoors
	14.7	73.2	292	Outdoors
Scalecide	1.2	98.1	2,978	Indoors
	9.9	81.8	4,043	Outdoors
Jarvis Compound	0	100	792	Indoors
	6	89.1	104	Outdoors

1. Quiescent nymph of European red mite, enlarged 80 times. 2. Larvae of predaceous enemy (*Stethorus punctum* LeConte). 3. Pupa and adult of same, enlarged 10 times. 4 and 5. Adult females of European red mite, enlarged 13 times. 6. Adult female, enlarged 80 times.

EUROPEAN RED MITE.

a. Apple leaves, showing leaf injured by European red mite (above), uninjured (below).



b. Peach leaves, showing leaf injured by European red mite (below), uninjured (above).

a. Infested apple tree which has lost much foliage from the attacks of the mite.

b. Eggs on calyx end of apple, and on twig, three times enlarged; insert, same from twig, enlarged about ten times.

EUROPEAN RED MITE.

a. View in orchard of Smith T. Bradley, North Branford, showing untreated trees partially defoliated by mite.

b. View in same orchard showing trees which were sprayed with linseed oil emulsion.

EUROPEAN RED MITE.

Notes.

Table 12. Eggs listed here were not treated with any insecticide. Numbers 1-11 were kept indoors in moist jars; 12-20 outdoors.

Table 13. The percentages in the column headed "possible kill" were obtained by comparing each with the check hatch, obtaining the actual hatch, and subtracting this number from 100, thereby obtaining the per cent. killed. Where the per cent. hatched is higher than the check it is obvious that the insecticide has no killing power.

SUMMARY OF VARIOUS TREATMENTS.

TABLE 14.

Exp. No.	Treatment	Hatched Per Cent.	Possible Kill Per Cent.	Number of Eggs Used
1.	Check, no treatment	55.2	0	9,550
2.	Kero-spray	74.1	0	743
3.	Sulco V. B	49.2	10.9	1,837
4.	Keresol	47.9	13.3	827
5.	Linseed oil emulsion	46.3	16.2	1,193
6.	B. T. S.	31.1	43.7	2,724
7.	Lime-sulphur (liquid)	30.8	44.3	6,111
8.	Lime-sulphur (dry)	26.3	52.4	1,191
9.	Kerosene emulsion	12.9	76.7	887
10.	Wormol	9.2	83.4	711
11.	Scalecide	7.6	86.2	7,021
12.	2% Red engine oil emulsion	4.8	91.3	646
13.	Jarvis compound	.6	99.0	896
14.	Sunoco spraying oil	.3	99.5	573

Different authorities have claimed that dormant or delayed dormant sprays of lime-sulphur either killed the mites before hatching, prevented them from reaching the leaves, or killed them by continued action after reaching the leaves. Although lime-sulphur will kill some of the eggs as shown in the tables, it has been our experience (see Table 15) that it does not prevent them from reaching the leaves or kill them off in appreciable numbers after they begin to feed. It is in fact a much less efficient ovicide for the red mite than miscible oils. A fairly convincing example of this is found in the table below, which gives the results of a test conducted at the Experiment Station Farm in 1923.

TABLE 15—EFFECT OF FIELD TREATMENTS ON THE WINTER EGG.

Treatment	Number of Fruit Spurs Examined	Number with Live Mites on Leaves	Per Cent. Infested
Scalecide 1-15	978	56	5.7
Lime-sulphur 1-9	975	972	99.6
Check, no treatment	1,000	1,000	100.0

Examination of the trees during the winter indicated a nearly equal infestation of all blocks. Sprays were applied at the latest possible date considering the development of the trees. Nearly a thousand fruit spurs in each block of about 20 trees were examined, every twig included having eggs on it or at its base. It

will be seen that lime-sulphur checked their development little or none, while the miscible oil used was considerably more effective.

This condition continued well into the summer and trees receiving lime-sulphur alone as a delayed dormant spray were in practically the same condition as those receiving no spray, that is, in the amount of infestation on the leaves. What virtue there is in lime-sulphur seems to rest mainly with early summer sprays and not so much with the delayed dormant. Early summer sprays at 1.5–50 or 1–50 have been successful in three different experimental orchards in keeping the mite in control—and this without any dormant or delayed dormant spray whatsoever. This, together with the information in Table 15, indicates that lime-sulphur dormant or delayed dormant sprays are of little value in red mite control.

It will be noted in Tables 7, 9 and 10 that there is a general reduction in percentage of hatch after treatments as the season advances from December to April or May. This is probably due to embryonic development, but the membranes do not split as in the case of aphids. The outer membrane, however, does loosen up and may be peeled off with a needle several days before the mite hatches. These facts were corroborated in practical experience at the Conyers Farm orchard at Greenwich, in charge of Mr. G. A. Drew. Fall spraying in this orchard with miscible oil killed a very small per cent., while spring applications were quite effective.

Scalecide is the only miscible oil which has been given a field test, and it is shown to be effective. There are other oil emulsions, however, which should do the work, and some, notably the home-made lubricating oil emulsions, apparently are causing no damage.[3] There is an element of danger in using them, and it is well to observe some precautions in applying.

1. Make sure that all of the oil emulsifies, leaving none floating on the surface of the water in the spray tank. This condition will often follow the use of old material which has been on hand for a year or more. In most cases it is best to have fresh stock.
2. Do not drench the trees; spray lightly, covering the outer twigs and smaller branches.
3. Do not spray in weather so cold that the spray freezes.
4. Apply before the buds break, as a late dormant spray. This usually falls several weeks before the *delayed dormant spray*.
5. Do not use at all unless red mite eggs are very numerous, or unless you expect a serious outbreak; an application of miscible oil once every three years should be sufficient when the mite is once in control.

Summer Sprays.

Different substances have been tested on the mites themselves for killing power, and the results are given below in Table 16. Such tests are not so satisfactory as similar tests for the eggs, be-

cause of the fact that the mite is susceptible to changes in temperature and also to condition of the food plant. At any rate, there is considerable more variation in the results obtained, though they indicate in a general way the effectiveness of soaps, lime-sulphur solutions, and oil emulsions.

TABLE 16—RESULTS OF LABORATORY TESTS TO CONTROL MITES.

Exp. No.	Insecticide Used	No. Dead	No. Alive	Per Cent. Dead	Temp. of Air F	Dates
1.	Ivory soap flakes 2 lbs. —50 gals.....	67	12	84.8		May 20–22
2.	Ivory soap 2 lbs.—50 gals. plus Melrosine 1 part to 100.....	71	14	83.5		May 20–22
3.	Ivory soap flakes 2 lbs. —50 gals.....	409	2	99.5	73	May 13–18
4.	Ivory soap flakes 2 lbs. —50 gals.....	406	4	99.0	80.5–82	May 13–18
5.	Lux 2 lbs.—50 gals...	107	1	99.0	73	May 13–18
6.	Lux 2 lbs.—50 gals...	164	3	98.1	80.5–82	May 13–18
7.	Potash fish oil soap 10 lbs.—50 gals.....	12	14	46.1		May 23–25
8.	Fish oil soap 5 lbs.— 50 gals.....	13	41	24.0		May 23–25
9.	Fish oil soap 10 lbs.— 50; sulphur 16 lbs. 50 gals.....	16	93	14.6	80.5–82	May 27–31
10.	Borax soap 4 lbs.—48 gals. water.....	128	26	83.1	60–79	Aug. 17–18
11.	Linseed oil emulsion 1 part—20 parts water	81	5	94.1	70–74	Aug. 17–18
12.	40% nicotine sulphate ¾ pt.—50 gals.....	114	5	95.7		July 28–30
13.	Borax soap 6 lbs.—50 gals.....	141	6	95.9		July 28–30
14.	Fels naphtha soap 4 lbs.—50 gals.....	15	0	100		July 28–29
15.	Star soap 4 lbs.—50 gals.....	23	2	92		July 29–30
16.	Dusted with sulphur..	22	59	27.1	73	May 12–18
17.	Dusted with sulphur..	101	2	98.0	80.5–82	May 12–18
18.	Lime-sulphur 1—40 nicotine sulphate 1 —500.....	36	2	95.0	60–79	Aug. 15–16
19.	Lime-sulphur 1—40; nicotine sulphate 1 —500.....	141	18	88.7	60–79	Aug. 17–18
20.	Ace-Hy 1—400†	108	254	29.8		June 31–July 1
21.	Ace-Hy 1—200†	40	2	95.2		Aug. 29
22.	Lime-sulphur 1—43¼ gals.....	79	28	73.8		July 28–30
23.	Check, no treatment..	4	53	9.5	73	May 12–18
24.	Check, no treatment..	22	31	41.7	80.5–82	May 12–18
25.	Check, no treatment..	12	70	14.6		May 20–22
26.	Check, no treatment..	2	84	2.3	60–79	Aug. 17–18

† An insecticide no longer on the market; containing cyanide (CN) as the active ingredient.

Sulphur dusts are variable, both in laboratory and in the field, but at least one factor influencing their effectiveness is found in the temperature of the atmosphere as shown in the two following charts, giving the killing power of sulphur dust and a dust containing 88 per cent. sulphur and 10 per cent. lead arsenate.

"Pomodust"† is now on the market and was apparently effective in controlling the red mite under the weather conditions experienced in 1923. The totally different action of sulphur dusts in

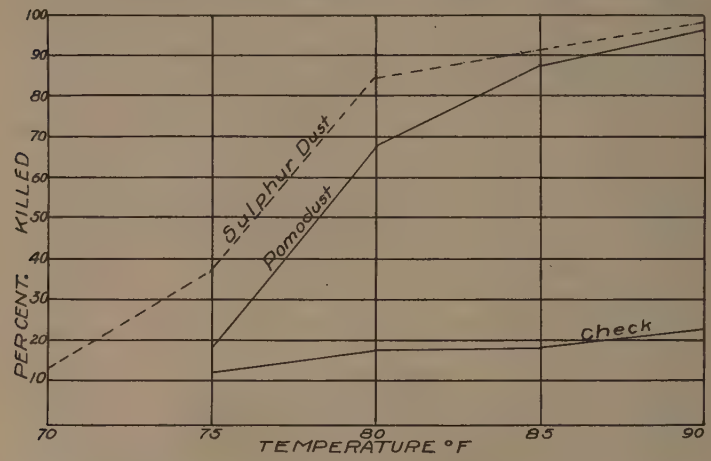


Chart 1. Showing kill obtained with sulphur dust and "Pomodust" at different temperatures; exposure in each case 24 hours.

1922 may be explained by the lack of excessive heat, and the dry weather which doubtless influenced the results in 1923.

Field tests have been conducted in five different orchards in Connecticut. The first were carried out at the Plant Brothers orchard in Branford in 1920. Soap, soap and nicotine sulphate, and sulphur-arsenate-nicotine dust were tried, but results were inconclusive due to the lateness of the applications. In 1921, no field tests were conducted but in 1922 serious outbreaks occurred and experiments were undertaken in three different orchards. Good control was secured with linseed oil emulsion, soaps, and a lime-sulphur-lead-arsenate-nicotine mixture. Tests at the Bradley orchard showed good control with linseed oil emulsion and with fish oil soap. Good control, however, was obtained with borax soap and lime-sulphur-lead-arsenate-nicotine combination in the

† Chemical analysis by the Connecticut Station, Department of Chemistry, showed that it contains sulphur 87.79 per cent., lead arsenate 9.80 per cent., and a trace of iron; water soluble arsenic .24 per cent.

Milford orchard of F. N. Platt. Counts were not made in the Milford orchard, but from a practical standpoint results were good, since the foliage continued green throughout the summer.

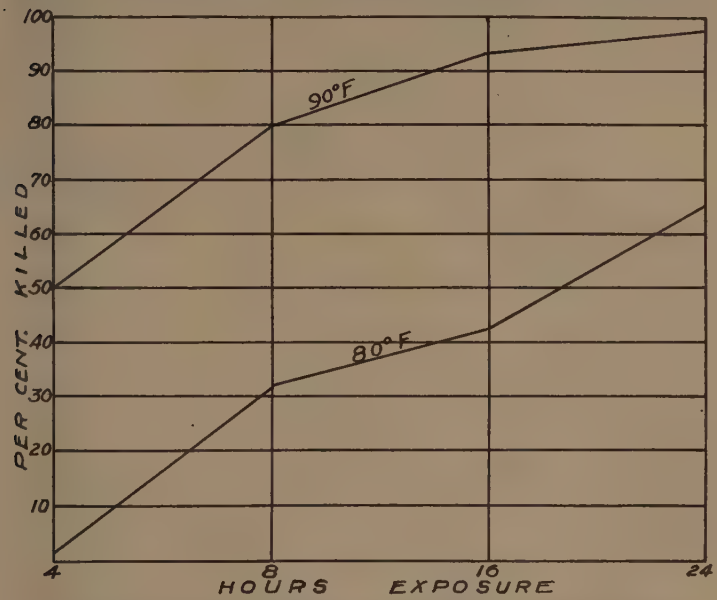


Chart 2. Showing kill obtained with "Pomodust" at different temperatures and different lengths of exposure.

TABLE 17—RESULTS OF FIELD TESTS WITH SOAPS, LINSEED OIL EMULSION AND SELF-BOILED LIME-SULPHUR IN BRADLEY ORCHARD.

Insecticide Used	No. Alive	No. Dead	Per Cent. Dead	No. of Leaves Examined	No. of Twigs Examined	Date of Treatment	Date of Examination 1922
Linseed Oil 1 gal.† Ivory soap 1½ lbs. Water 100 gals...	718	1,524	67.9	80	10	June 2	June 6
Ivory soap 6 lbs. Water 200 gals...	1,743	779	30.8	60	9	June 2	June 6
"Kerospray" 1 gal. —100 gals.....	916	381	29.5	50	6	June 2	June 6
Fish oil soap 14 lbs.—200 gals..	691	655	48.6	54	6	June 2	June 7
Self-boiled lime-sulphur (8-8-50)							
Kayso 2½ lbs.— 200 gals.....	951	356	27.2	64	8	June 2	June 8
None.....	1,592	278	14.	65	7	———	June 8

† Prepared according to directions in Mass. Agr. Exp. Sta. Bull. 179, pages 175-6, except that flakes were used instead of bars of soap.

Continued experimentation in 1923 in the orchard at the Experiment Station Farm and in the orchard at Conyers Farm, Greenwich, substantiated the results in 1922 except for the use of fish oil soap, the results in this case not appearing so favorable as in 1922, and the foliage turning brown before the end of the summer. Two different counts were made in both orchards, and the results are shown in Tables 18 and 19.

TABLE 18—RESULTS OF SPRAYING AT STATION FARM.

EXAMINATION JUNE 21 AND 22, 1923.

Treatment Received	Date of Treatments	Condition of Leaves	No. Leaves Examined	Total No. Eggs Per 100 Leaves	Total No. Live Mites Per 100 Leaves	Total No. Cast Skins Per 100 Leaves	Total No. Dead Mites Per 100 Leaves
1. Lime-sulphur Nicotine Sulphate Lead Arsenate.. Kayso and Lime	May 11 May 29–31 June 14 June 26	Green	100	16	1	33	14
2. Lime-sulphur Lead Arsenate Kayso and Lime	"	Green	125	7	6	303	43
3. No treatment	.....	Green	100	606	190	306	281

EXAMINATION AUGUST 22, 1923.

1. Lime-sulphur Nicotine Sulphate Lead Arsenate Kayso and Lime	.....	Green	25	54	8	572	...
2. Lime-sulphur Lead Arsenate Kayso and Lime	.....	Green	25	48	16	240	...
3. No treatment	.....	Slightly browned	10	12	10	13,580	4

TABLE 19—RESULTS OF SPRAYING AT CONYERS FARM.

EXAMINATION JUNE 12, 1923.

Treatment Received	Date of Treatments	Condition of Leaves	No. Leaves Examined	Total No. Eggs Per 100 Leaves	Total No. Live Mites Per 100 Leaves	Total No. Cast Skins Per 100 Leaves	Total No. Dead Mites Per 100 Leaves
1. Lime-sulphur 1—50	May 2 May 24 June 26	Green	225	3	2	130	3
2. Lime-sulphur followed by linseed oil emulsion	May 2 May 24 June 26	Green	100	39	61	71	88
3. Check, no treatment	.....	Turning brown	50	286	1,220	1,094	258
4. Lime-sulphur plus nicotine sulphate	May 2 May 24 June 26	Green	160	3	6	178	16
5. Lime-sulphur plus Kayso and Sulphur	"	Green	210	11	26	227	25
6. Fish Oil Soap and Sulphur	"	Green	200	25	29	196	38

TABLE 19. RESULTS OF SPRAYING AT CONYERS FARM—*Continued.*

EXAMINATION AUGUST 2, 1923.

Treatment Received	Date of Treatments	Condition of Leaves	No Leaves Examined	Total No. Eggs Per 100 Leaves	Total No. Live Mites Per 100 Leaves	Total No. Cast Skins Per 100 Leaves	Total No. Dead Mites Per 100 Leaves
1. Lime-Sulphur 1—50	.....	Green	25	212	44	592	40
2. Lime-sulphur 1—50 followed by linseed oil emulsion	.....	Green	25	328	168	5,590	120
3. Check, no treatment	.....	Brown	25	20	25	18,300	4
4. Lime-sulphur plus nicotine sulphate	.....	Green	25	140	44	3,476	16
5. Lime-sulphur plus Kayso and Sulphur	.....	Green	25	32	8	1,562	0
6. Fish oil soap and Sulphur	.....	Brown	25	1,648	544	10,300	280

Notes.

Table 18. Insecticides used at the following strengths in all tests. Lime-Sulphur 1.5 gal. to 50 gals.; nicotine sulphate .5 pint to 50 gals.; Lead arsenate 1.5 lbs. to 50 gals.; Kayso .75 lb. to 50 gals.; hydrated lime 1.5 lbs. to 50 gals.

Table 19. Insecticides used at following strengths. 2.—One per cent. linseed oil emulsion. 4.—Lime-sulphur 1 gal. to 50 gals., nicotine sulphate 6 oz. to 50 gals. 5.—Lime-sulphur .5 gal. to 50 gals., Kayso .75 lbs. to 50 gals., sulphur 5 lbs. to 50 gals. 6.—Potash fish oil soap 5 lbs. to 50 gals., sulphur 5 lbs. to 50 gals.

Cast skins left upon the leaves gave a reliable index of the efficiency of a spray in 1923, the total number found indicating how many mites had been present. Thus at the Experiment Station Farm, examination August 22, check trees showed twenty to fifty times as many cast skins per leaf as in the case of trees sprayed with lime-sulphur. At the Conyers orchard the check trees had from six to thirty times as many casts as could be found on trees sprayed with lime-sulphur. This seems to be more reliable than judging the foliage greenness, which may be affected by a number of causes. It will also be seen that no conspicuously greater control was obtained with lime-sulphur to which nicotine alone was added than with lime-sulphur combinations containing no nicotine. Lime-sulphur combinations thus far have not failed in a single instance under our observation to control the red mite successfully if applied according to spray calendar recommendations, especial attention being given to early summer sprays.

Mineral oil and linseed oil emulsions are very effective in killing mites—apparently more so than lime-sulphur if the count is made shortly after the spray is applied. They have given uniform results of this kind in every instance and there is no reason why linseed oil emulsion (or other safe spraying oil) cannot be used to advantage on trees unable to stand commercial lime-sulphur. For

apples their use seems to be needless in view of more efficient fungicidal effects of lime-sulphur. Soaps are likely to vary, and while their combination with sulphur may be effective at times, even this combination may fail to give good results. Probably their continued effect is dependent upon heat as with sulphur dusts already mentioned. A field test of three oil emulsions is shown in Table 20.

TABLE 20. EUROPEAN RED MITE CONTROL AT CONYERS ORCHARD.†

SPRAYED JUNE 25, 1923.

Exp. No.	Insecticide Used	Number Live Mites.	Number Dead.	Per Cent. Dead.	Possible Kill Per Cent.
1.	Sunoco spraying oil 1 part in 100 parts water.....	6	395	98.5	98.1
2.	Linseed oil emulsion 1 gallon linseed oil 1¼ lbs. Ivory soap 100 gallons water	30	177	85.5	82.5
3.	Schnarr's insecticide 1 part in 100 parts water.....	28	412	93.5	92.6
4.	None	241	61	20.1	0.0

Notes.

Trees in experiments 1 and 3 sprayed with hand pump and rod, 2 with gun and power outfit.

SPRAY BURN RESULTING FROM SPRAYS CONTAINING LIME-SULPHUR.

The main objection to the use of lime-sulphur solution has been due to burning of the foliage. Severe spray burn was noticed in different sections of Connecticut in 1923 and notes upon the probable cause are timely. As the spray formula consists of several compounds, the following possibilities arise:

1. The cause of the spray burn may be the lime-sulphur solution—due to composition or strength.
2. It may be due to lead arsenate alone—due to high water soluble arsenic content.
3. It may be due to nicotine sulphate—especially combination products with other insecticides.
4. It may be due to a combination of all of these materials resulting in other compounds or altered original compounds which cause burning.
5. Weather conditions noticeably affect the degree of spray burn.
6. The particular variety may be susceptible to spray injury.

† Leaves collected immediately after treatment and examined the following day.

Considering these causes in order, with precautions necessary to avoid injury, it seems advisable:

1. To reduce the strength of lime-sulphur on tender varieties such as Baldwin from 1½ to 50 gallons to 1 to 50 or even 1 to 75 in the later applications.

2. To obtain a guarantee that the lead arsenate used shall contain no more than .75% of water soluble arsenic. If large quantities are purchased have the material analyzed for water soluble arsenic at the Experiment Station or elsewhere.

3. Omit nicotine sulphate unless aphids are present in the orchard.

4. Combine your sprays in the following order:

1. Lead arsenate
2. Nicotine sulphate
3. Casein lime
4. Lime-sulphur.

Do not allow sludge to collect in the bottom of the spray tank; clean frequently.

5. Do not spray when the temperature or humidity is high. It is best to stop when the temperature reaches 90 degrees.

6. Be particularly careful with Baldwin and other thin leaved varieties. If the trees continue to be burned, use formula[3] containing lime-sulphur, casein lime and sulphur as follows:

Water	100 gallons
Lime-sulphur	1 gallon
Finely ground sulphur	5–10 lbs.
Casein lime	1 lb.

Summary and Recommendations.

1. The European red mite passes the winter in the egg stage upon smaller twigs and branches. Eggs hatch in April or May at the time fruit buds are turning pink.

2. The incubation period of the summer egg varies from six to thirteen days, and the adult develops in five to ten days. The preoviposition period lasts from one to seven days, but eggs are usually laid within a few days after emergence. Adults lived six to nineteen days and adult females laid a total of sixteen to thirty-four eggs during their lives. Winter eggs are sometimes laid in August; usually however during September and early October. Winter eggs are dark red, summer eggs, brown.

3. This mite is easily distinguished from other species in adult and egg stage.

4. An infestation of 50 to 100 mites per leaf is sufficient to cause leaves of apple trees to turn brown. Baldwin is the variety most commonly injured.

5. Enemies become numerous in July and August and are often responsible for the disappearance of the red mite.

6. Dry weather in summer favors their development and a wet period with frequent showers keeps them in check.

7. A definite spray schedule should be adopted in orchards where mites are numerous.

8. Lime-sulphur delayed dormant spray is not effective because of the late hatching of the egg.

9. Miscible oils are effective dormant sprays, and with care are reasonably safe in orchard work. Fall sprays of miscible oil are apparently ineffective.

10. Lime-sulphur, summer strength, sprays should be applied early beginning with the pink spray, which should be followed by at least two others containing lime-sulphur, the latest being applied the last of June or first of July.

11. Nicotine sulphate is unnecessary in the spray mixture so far as mite control is concerned.

12. Soaps, miscible oils and linseed oil emulsion are very effective summer sprays, but needless and apparently less efficient in control of fungous diseases than lime-sulphur.

13. Care should be exercised in applications of lime-sulphur and the precautions noted on page 123 carefully observed.

Acknowledgments.

In the course of the work outlined in the present paper, several persons have aided materially. Dr. W. E. Britton, and Messrs. M. P. Zappe, B. H. Walden, E. M. Stoddard and G. E. Graham have given invaluable service. The use of orchards belonging to the Plant Brothers at Branford, S. T. Bradley of North Branford, F. N. Platt of Milford, as well as the Conyers orchard at Greenwich, managed by Messrs. G. A. Drew and H. B. Reed, has increased the scope of the work immeasurably. Thanks are due to all persons in charge of orchards, without whose aid orchard field work would have been impossible; and to those who have given personal service and advice throughout the period of these investigations.

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